Revegetation studies on disturbed overburden: Alton coal field: 1980 annual progress report

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REVEGETATION STUDIES ON DISTURBED OVERBURDEN

ALTON COAL FIELD

by

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FOREST SERVICE REVEGETATION STUDIES AT THE ALTON COAL FIELD, UTAH

Eight studies at the Alton coal field which began in 1976 or soon thereafter are being monitored to determine which species of shrubs, grasses, and forbs prove superior on different types of soils over a period of years. These studies have been enumerated and described in detail in previous reports, and this report will present 1980 data according to previous study number. In each case, sufficient background material is presented to preserve continuity without referring to previous reports except for plot diagrams. In some cases, prior years' data are presented in addition to 1980 data to show changes with time.

In addition to the eight studies mentioned above, and the microclimate study (No. 9), three new studies were begun in 1980 to satisfy requirements of the cooperative agreement. These new studies are also covered in this report.

Study No. 1 (Revegetation Techniques on Disturbed Overburden from Simulated Mining)

Objectives: (1) to evaluate three different soil surface cultural treatments following severe site disturbance termed "simulated mining." (2) to compare effects of simulated mining and no simulated mining on plant establishment and growth.

Methods

An 8-acre (3.2 ha) site (464 x 800 feet or 139 x 240 m) covered by an old-growth juniper-pinyon stand was cleared and fenced to exclude deer and rabbits. Simulated mining involved stockpiling topsoil, ripping the subsoil to a depth of 30 inches (76 cm), smoothing the furrows with a dozer blade, and replacing the topsoil. Treatments are listed below, according to the same number shown on plot diagrams in earlier reports:

0. Topsoil left in place, gouged (two 32-foot-wide strips where topsoil had been piled).

1. Topsoil removed, subsoil ripped, topsoil replaced, gouged.

2. Topsoil left in place, gouged (two areas of about 1/2 acre, each, on opposite ends of the site).

3. Same as No. 1 but contour furrowed and not gouged.

4. Same as No. 1 but grass hay mulch spread at 2-1/2 tons per acre, rotovated, not gouged.

A seed mixture of the species shown in Table 1 was broadcast over all four treatments using hand-operated cyclone seeders, in December 1976.

Table 1. Seed mixture used on larger study areas at Alton Coal Field

	Lbs/ac	Kg/ha
Intermediate wheatgrass*	4	4.50
Pubescent wheatgrass	4	4.50
Fairway wheatgrass	4	4.50
Russian wildrye	4	4.50
Nomad alfalfa	1	1.10
Yellowblossom sweetclover	1	1.10
Bitterbrush	2	2.25
Fourwing saltbush	2	2.25
Winterfat	0.5	0.55
Green ephedra	1	1.10
Cliffrose	1	1.10
Total	24.5	27.45

*Scientific names, common names, and species symbols are shown in the Appendix.

Results

The severe drought during the autumn of 1976 and first 4-1/2 months of 1977 precluded normal early spring germination and emergence of seeds sown in December 1976. However, fair to good germination and emergence occurred on all treatments following a rainy period in the latter half of May 1977 (2.34 inches at Alton).

The most striking difference the first year among these treatments was higher frequency and numbers of grass seedlings on the area where hay was rotovated into the soil surface. At the end of the 1977 growing season, presence of grass seedlings on square-foot (0.09 m^2) plots showed 92 percent frequency on the area treated with grass hay compared to 52 percent frequency on the areas not treated with hay. Frequency of forbs was 40 percent and 21 percent on hay and non-hay areas, respectively. Comparable shrub frequencies were 4 percent and 2-1/2 percent. The most prominent shrubs were fourwing saltbush, winterfat, and bitterbrush, in that order. Mean maximum numbers of grass seedlings per square foot (0.09 m^2) was 12.8 for hay-treated plots compared to 5.2 on plots not treated with hay.

All surface cultural treatments were effective in limiting runoff from high-intensity summer storms in 1977. Some sediment was deposited in the bottoms of terraces and pits, but the result was not serious. Minor repairs were made where a few small channels developed, mainly in wheel tracks left by equipment. No such storms occurred on this site in 1978.

Above-average precipitation during the winter of 1977-78 produced excellent growth of vegetation in the spring of 1978. Smooth brome was a prominent component of grasses where hay was used, indicating that seed of this species was present in the hay used as an organic amendment.

Table 2 shows frequency of grasses, legumes, and shrubs by treatment for the years 1977 through 1980, plus yields in 1979 and 1980. Plant frequency in 1978, 1979, and 1980 does not include the smooth brome component in treatment No. 4. Even so, it is apparent that frequency remains highest where hay mulch was used, even without the smooth brome component. Likewise, yields in 1979 and 1980 for that treatment does not include smooth brome. Adding the smooth brome component would make the 1979 and 1980 yields 1950 and 1353 lbs/acre, respectively. Of course, smooth brome is not a component of grass yields on the other four treatments.

A noticeable increase in frequency of grasses occurred in all treatments from 1977 to 1980. This results mainly from increase in size of plants plus some reproduction. Considering legumes, the 1977 frequency includes both alfalfa and sweet clover. Data shown for 1978 and 1979 include only alfalfa. Sweet clover was a major component of the vegetation in 1978, and its frequency was approximately one-half that of alfalfa. In 1979, frequency of sweet clover was almost nothing. The yields in 1979 were for alfalfa only. Inasmuch as sweet clover is a biennial, prepetuation of this species depends upon successful seedling establishment every other years.

Frequency of shrubs in 1980 declined noticeably on some treatments, particularly for fourwing saltbush and white sage. Whereas fourwing saltbush was the most prominent shrub in 1977, bitterbrush was the most prominent shrub in 1979 and 1980. Obviously a dense grass stand offers keep competition to the shrubs used in this study.

Because of the general success of all treatments, it is questionable whether the additional expense incurred by use of a grass-hay mulch is justified. These areas will be monitored for a few more years to determine more specifically the advantages of certain treatments.

Table 2. Frequency (percent) and yield (lbs/acre, airdry) of plants according to treatment and year at Alton.

Treatment	Year	Grass		Legumes		Shrubs	
		Freq.	Yield	Freq.	Yield	Freq.	Yield
0 = No simulated mining, gouged	1980	63[ab] 1/	1664[a]	12[ab]	897[a]	1	--
	1979	60	1400 2/	16	490	2	--
	1978	57	--	14	--	4	--
	1977	43	--	21	--	2	--
1 = Simulated mining, gouged	1980	75[ab]	1123[b]	15[a]	535[ab]	1	--
	1979	71	1325	16	430	3	--
	1978	67	--	19	--	4	--
	1977	52	--	21	--	3	--
2 = No simulated mining, gouged	1980	73[ab]	828[c]	4[b]	195[b]	3	--
	1979	70	895	10	105	4	--
	1978	61	--	13	--	5	--
	1977	40	--	17	--	1	--
3 = Simulated mining, contour	1980	53[b]	903[b]	17[a]	765[ab]	2	--
	1979	58	1675	16	765	3	--
	1978	64	--	22	--	9	--
	1977	53	--	22	--	8	--
4 = Simulated mining, grass-hay ~~mulch~~ amendment	1980	89[a]	877[bc] 3/	21[a]	630[ab]	1	--
	1979	87	1350	14	170	1	--
	1978	76	--	19	--	5	--
	1977	92	--	40	--	4	--

1/ Column figures for 1980, followed by the same letter are not significantly different (P < .05).

2/ Dry weight for 1979 was estimated to be 50% of green weight.

3/ With smooth brome added, yield for this treatment would be 1353 lbs/acre in 1980, and 1950 lbs/acre in 1979.

Study No. 2 (Effects of Organic Amendments on Growth of Selected Grasses)

Objectives: (1) To determine to what extent organic mulches (grass hay and bark-woodfiber compost) can improve grass growth and production on subsoil and replaced topsoil. (2) To compare response of six introduced grasses with four native grasses on different soils and amendments.

Methods

This study, established on a part of the 8-acre (3.24 ha) Alton site, involved testing the effects of all combinations of two soil types and three organic amendments on growth of 10 selected grasses. Soil types included: (1) topsoil replaced over subsoil after simulated mining, and (2) subsoil only. Soil amendments included: (1) grass hay spread at 2-1/2 tons per acre (0.9 metric tons/ha) and rotovated into the soil; (2) bark-woodfiber compost spread 1 inch (2.5 cm) deep and rotovated into the soil; and (3) no amendment. Seeds of 10 selected grasses were planted in small subplots on each of the six larger main plots in a randomized block design having three replications.

Results

Seed germination and emergence of grass seedlings did not occur until late May 1977. Cursory observations in mid-June while seedlings were still small and not fully established showed more seedlings present where organic amendments had been used. At the end of the first growing season (1977), grass seedlings were most numerous on the grass hay amendment plots and fewest on the bark-woodfiber compost plots. First-year survival of streambank (Agri) and fairway (Agcr) wheatgrasses was superior among the 10 species, whereas western wheatgrass (Agsm) and Great Basin wildrye (Elci) showed fewest plant numbers. Differences among the other six grasses were less important. These six species in descending order of maximum plant numbers were Russian wildrye (Elju), intermediate wheatgrass ($Agin^2$), smooth brome (Brin), tall wheatgrass (Agel), beardless bluebunch wheatgrass (Agin), and pubescent wheatgrass ($Agtr^2$).

In the second growing season (1978), many smooth brome plants were oberved on plots where the grass hay was used as a mulch amendment. Obviously, seeds were present in the hay which added to the total amount of seed distributed.

Data obtained in 1980 included plant yields, plant frequency, and leaf heights by species and treatments. As in 1979, yields of plants on topsoil in 1980 were significantly higher than yields on subsoils, but there was no significant difference between mulches (Table 3). Yields were obtained by the weight-estimate method. organic amendments

Table 3. Means of grass yields (lbs/acre, airdry) according to soil and mulch treatments*

Topsoil check	Topsoil compost	Topsoil hay	Subsoil compost	Subsoil hay	Subsoil check
854	904	799	415	407	315

* Yields underscored by the same line are not significantly different (P <.05).

Considering the 10 grasses planted, highest yields in 1980 were obtained from three introduced wheatgrasses (Table 4). The four native species (streambank, beardless bluebunch, and western wheatgrass, plus Great Basin wildrye) showed generally lower herbage production in 1980 than most introduced grasses. Lowest production from an introduced grass was obtained from Russian wildrye. In general, smooth brome that originated from the hay mulch was most prominent on grass plots having lowest yields. The smooth brome component is not shown.

Table 4. Mean yields (lbs/acre, airdry) of 10 grass species*

Agcr	Agin[2]	Agel	Brin	Agin	Agtr[2]	Elci	Agri	Elju	Agsm
882	791	727	698	641	624	558	541	444	243

* Means underscored by the same line are not significantly different (P < .05).

Considering frequency on the 10- x 15-foot plots, crested wheatgrass and streambank wheatgrass showed highest frequency through 1979, but smooth brome forged ahead of streambank wheatgrass in 1980 (Table 5). Lowest frequencies again were obtained from bluebunch and western wheatgrasses and Great Basin wildrye. Frequency is determined by presence of a species on each of 10 square-foot subplots within a 2- x 5-ft plot frame used for sampling.

Table 5. Percent frequency of 10 grass species on small plots*

Agcr	Brin	Agri	Agin[2]	Agtr[2]	Elju	Agel	Agin	Agsm	Elci
84	84	80	77	74	74	71	67	54	25

* Means underscored by the same line are not significantly different (P < .05).

Frequency data show the advantage of including both native and introduced species in revegetation programs. Although lower in frequency at present, it is expected that a rhizomatous species such as native western wheatgrass will continue to increase in plant cover and yields, but it is highly important that the more vigorous introduced grasses such as intermediate, tall, and crested wheatgrasses and smooth brome be included in seeding mixtures. These species can initiate early establishment of good ground cover.

The addition of a hay amendment would not be recommended where topsoil is replaced over subsoil materials. Where topsoil is unavailable and subsoil must be placed on the surface, it is likely that a hay ~~mulch~~ would improve seedling establishment. This is a refinement of statements in the earlier report relative to grass hay amendments. amendment

Data on mean leaf height in 1980 show that a mixture of species can create habitat diversity for wildlife and birds (Table 6). Great Basin wildrye had the tallest culm height as well as leaf height, followed by intermediate and tall wheatgrasses. The shortest culm height was exhibited by fairway crested wheatgrass, but Russian wildrye had the shortest leaf height.

Table 6. Mean leaf height (inches) for 10 grass species*

Elci	Agin[2]	Agel	Agin	Agtr[2]	Brin	Agcr	Agsm	Agri	Elju
21.5	14.7	13.4	12.2	11.7	10.3	8.6	7.9	7.6	6.6

* Means underscored by the same line are not significantly different (P < .05).

Study No. 3 (Adaptability of Selected Grasses and Shrubs on Different Profile Materials)

Objectives: To determine the effectiveness of different grass and shrub species in forming suitable cover on different subsoil materials as well as on topsoil.

Methods

The study was established on four different types of overburden above the coal seam on a 3-acre (1.2 ha) site having a 20 to 25 percent slope and a westerly exposure. Juniper and pinyon trees were bulldozed from the areas above and below the cut area where the coal seam was exposed. The high sidewall was reduced by developing two terraces each about 25 feet (7.6 m) wide and 220 feet (67 m) long in the cut area. A 4- to 5-foot- (1.2 to 1.5 m) deep layer of dark, carbonaceous shale that lay just above the coal seam was exposed on the surface on both terraces. Three additional strips, each 50 x 220 feet (15 x 66 m), two above and one below the terraces, were prepared with different types of overburden on the surface. Starting at the top of the hill, the sequence of the four treatments was as follows:

(1) A 50- x 220-foot (15.2 x 67 m) strip of topsoil was left in place but ripped with dozer teeth to prevent runoff.

(2) A 50- x 220-foot (15.2 x 67 m) plot was stripped of approximately 1 foot (30 cm) of topsoil and 2 feet (61 cm) of gravelly clay subsoil leaving a light-colored, clay-shale surface exposed. This plot was also ripped to a depth of about 2 feet (61 cm) and furrows were left to prevent runoff and erosion.

(3) Two 25-foot- (7.6 m) wide terraces were formed where dark carbonaceous shale was exposed on the surface.

(4) A 50-foot- (15.2 m) wide strip of "fill" material consisted of the gravelly clay subsoil from (2) above.

On each of these four soil types, 12 grass species were seeded in separate plots, 10 feet wide and 50 feet long (3 m x 15 m), in two replications, except that Agcr(r) and Agsp x Agre were seeded in plots 25 feet long due to shortages of seed.

Results

The drought during the autumn and winter of 1976-1977 prevented early spring germination of seed, but good seedling emergence occurred in late May 1977. By the end of the first growing season, survival of the seeded grasses could be considered only fair to good. Ranking of the above four treatments in descending order of plant establishment and growth was: 1,4,3,2. All grass species exhibited fair to good growth, but some were superior to others.

Data taken in 1980 included yield, frequency, and height of plants by species and treatment. It is obvious from Table 7 that topsoil and gravelly-clay subsoil are superior to the blue clay and dark shale that occur lower in the soil profile.

Table 7. Mean yields of grasses (lbs/acre dry wt.) according to the four soils,* 1980.

Topsoil (1)	Gravelly-clay (4)	Dark shale (3)	Blue clay (2)
677	660	356	134

*Means underscored by the same line are not significantly different (P<.05)

Also, certain grasses are more productive than others which is reflected in lant height as well as yield. In 1980, as in 1979, tall wheatgrass and intermediate wheatgrass were the two most productive species (table 8). Also, these two species were tallest with the exception of Great Basin wildrye (table 9). The latter species has greater height growth than any other as would be expected, and in time, yields will greatly increase.

A reason for the lower yields of Great Basin wildrye at present, despite excellent height growth, is low frequency for this species (table 10). To 1979, this species and western wheatgrass, two native species, had shown lowest frequency of any of the 12 grasses since they were planted. Of course, western wheatgrass is rhizomatous and will continue to show increased plant frequency and yield with time. All species are proving to be well adapted on these soils. Any or all could be recommended for planting in mixtures on this site. Thus far, with the exception of Great Basin wildrye, the introduced wheatgrasses are generally superior from the standpoint of productivit to native specie . It is important that data be obtained for several years in order to reflect the true adaption of all species on the various soil materials.

Table 8. Mean yields (lbs/acre dry wt.) of 12 grasses.*

Agel (3)	Agin[2] (5)	Brin (10)	Elci (11)	Agcr (1)	Agtr[2] (9)	Agri (6)	Agcr(H) (2)	Agin (4)	Agsp x Agre (8)	Elju (12)	Agsm (7)
1071	704	697	618	402	380	338	337	279	248	204	203

* Means underscored by the same line are not significantly different (P<.05)

Table 9. Mean culm height (inches) for 12 grasses over all soils.*

Elci (11)	Agel (3)	Agin[2] (5)	Agtr[2] (9)	Brin (10)	Elju (12)	Agsp x Agre (8)	Agin (4)	Agri (6)	Agsm (7)	Agcr(H) (2)	Agcr (1)
46.3	34.1	31.6	29.1	28.6	24.8	23.8	21.8	17.9	17.6	15.9	15.1

*Means underscored by the same line are not significantly different (P<.05)

Table 10. Percent frequency of 12 grasses.*

Brin (10)	Agin[2] (5)	Agtr[2] (9)	Agsm (7)	Agri (6)	Agel (3)	Agcr (1)	Elju (12)	Agcr(H) (2)	Agin (4)	Agsp x Agre (8)	Elci (11)
73	66	64	63	58	58	54	44	43	43	40	34

*Means underscored by the same line are not significantly different (P<.05)

Study No. 4 Establishment and Longevity of Several Plant Species on Various Topsoils and Shaley Overburden

Major holders of coal leases on the Alton Coal Field of southern Utah are interested in learning what types of soil material can be successfully used as a growing medium for plants. They want to know whether or not it will be essential to cover surface mining overburden with high quality topsoil in order to establish a good, permanent vegetative cover on reclaimed land following mining. The mining companies believe that carbonaceous shales, which occur just above most coal seams, will be the most abundant type of overburden and have suggested the possibility of using carbonaceous shale on or near the surface of reclaimed areas.

The Intermountain Forest and Range Experiment Station and Utah International Incorporated conducted a cooperative study east of Bald Knoll, on the Alton Coal Field, from 1976 through 1980. Objectives of the study were: (1) to test the possibility of establishing vegetation on a carbonaceous shale without topsoil and on carbonaceous shale covered with three different kinds of topsoil, (2) to monitor soil moisture and salinity changes in topsoils and shale, and (3) to determine the physical and chemical properties of the three topsoils and carbonaceous shale used in the study.

An 0.5-acre (0.2 ha) area approximately 7 miles (11.2 km) southeast of Alton, Utah was fenced to exclude deer, livestock, and rodents. Within the exclosure, four soil materials were placed in plots 10 x 30 feet (3 m x 9 m) in size that had been excavated to a depth of 40 inches (100 cm), replicated four times. Soil materials included: (1) shale overburden taken from directly above a coal seam, (2) sandy loam topsoil, (3) loam topsoil, and (4) silty clay topsoil. Each of the topsoils, which are common to portions of the coal field, was spread to a depth of 10 inches (25 cm) over a 30-inch (76 cm) layer of the shale overburden that had been placed first in the excavated pits. Sensors for monitoring soil moisture and salinity were placed at depths of 8, 18, and 30 inches (20, 46, 76 cm) in each plot. One-half of each plot was fertilized with 80 lb/acre (90 kg/ha) of both elemental nitrogen and phosphorous, and all plots were broadcast-seeded with a mixture of six grasses, six forbs, and six shrubs, in November 1976. Measurement of plant density and ground cover was to be made each year for 3 years. Plant productivity was to be measured near the end of the third growing season.

Seed germination was delayed by lack of soil moisture until late May 1977. Although seedling establishment appeared adequate on the sandy loam topsoil and on the shale overburden for satisfactory vegetative cover, all plots were reseeded in November 1977, in an effort to obtain better vegetative stands.

Chemical and physical analyses showed that other than being low in available nitrogen, none of the three topsoils or the carbonaceous shale were unsuited to plant growth. Electrical conductivity of the soil extract ranged from 0.6 mmhos/cm for the sandy loam topsoil to 3.3 mmhos/cm for the carbonaceous shale overburden. The sodium adsorption ratios ranged from 0.5 meq/l for carbonaceous shale to 3.1 meq/l for the silty clay topsoil.

The carbonaceous shale rapidly weathers to a clay loam texture. Throughout the remainder of this report, we will refer to the carbonaceous shale as clay loam soil material.

In the second growing season (1978), "drylander" alfalfa from Saskatchewan provided most of the vegetative cover on all plots. Fairway crested wheatgrass showed good establishment and vigor and was expected to ultimately form a substantial portion of the vegetative stand on most plots. Excellent individual plants of Russian wildrye, Indian ricegrass, small burnet, globemallow, winterfat, and fourwing saltbush also occurred. Shrub species such as true mountain mahogany, green ephedra, and antelope bitterbrush failed to exhibit good growth on any of the soils.

By the end of the second growing season (1978), best overall vegetative cover had been obtained on plots having 10 inches (25 cm) of sandy loam topsoil spread over the clay loam soil material, followed by the loam topsoil over clay loam. At that time, the clay loam ranked third among the four growing media in vegetative cover.

By the end of the third growing season (1979), overall plant density (number of plants per unit area) had decreased from the previous year's level; especially on the clay loam plots (Table 11). Much of the loss in plant numbers on the clay loam plots was among grass species. This was not unexpected, because a large number of grass seedlings had emerged in 1978 from the second seeding in the autumn of 1977. Competition was almost certain to result in thinning the seedling stand.

Although total plant numbers decreased on all except one of the 16 plots, numbers of "drylander" alfalfa plants increased on two or more of the four plots of each of the four soil materials (an increase occurred on all four plots of the silty clay topsoil plots).

At the end of the 1979 growing season, total plant density was essentially equal on all soil materials except for the silty clay topsoil. The latter exhibited only 50 percent of the plant density occurring on the other soil materials.

Table 11. Comparison of mean number of plants per square meter after 2 and 3 years on four soil material combinations

Species	Clay loam (40")		Three topsoils (10") over 30" clay loam: Sandy loam		Loam		Silty clay	
	1978	1979	1978	1979	1978	1979	1978	1979
Crested wheatgrass	20.7	14.6	27.0	24.9	21.9	17.6	6.8	3.8
Tall wheatgrass	3.9	2.6	4.7	3.4	6.1	6.4	.9	1.1
Western Wheatgrass	1.0	.4	.7	1.1	2.9	2.6	.9	.2
Russian wildrye	4.4	1.5	5.2	1.3	5.0	2.6	1.6	1.8
Indian ricegrass	.6		.1	.1	.4		.6	
All grasses	30.6	19.1	37.7	30.8	36.3	29.2	10.8	6.9
Alfalfa	17.7	17.4	10.8	11.8	8.9	10.3	5.9	10.6
Small burnet	5.8	3.0	4.2	1.0	3.3	2.0	2.0	1.6
Cicer milkvetch	6.1	1.2	1.8	.1	1.6	.3	1.7	.8
Globemallow	.4		.2	.1	.3			
All forbs	30.0	21.6	17.0	13.0	14.1	12.6	9.6	13.0
Fourwing saltbush	1.2	.9	.8	.4	.6	.2	1.5	.8
Winterfat	3.1	.6	5.4	.1	1.3	.1	1.5	.6
All shrubs	4.3	1.5	6.2	.5	1.9	.3	3.0	1.4
Total	64.9	42.2	60.9	44.3	52.3	42.1	23.4	21.3

Assessing the success of revegetation on the basis of plant density alone may not be wise because of possible differences in plant size. At the end of the 1979 growing season, estimates were made of the percent of soil surface covered by each plant species. These estimates were made on the same sample plots used to tally plant density. On each of the 16 individual study plots (10 x 30 ft), 24 square-foot sample plots were examined, constituting an 8-percent sample of the larger plot. Table 11 shows the mean percent ground cover by plant class (grasses, forbs, and shrubs) for four replications of each of the four soil materials studied. Values of percent cover are given for each of the 3 years of observation.

Percent ground cover increased each year on all soil materials, through 1979, and was not measured in 1980. The growing medium of 10 inches of sandy loam over 30 inches of clay loam (shale overburden) produced the most plant cover, with loam over clay loam and clay loam alone being about equal. Whereas the growing medium of silty clay over clay loam exhibited only one-half the plant density as the other media, percent cover was 78 to 93 percent of that on plots of the other three media. On the loam plots, grasses made up 60 percent of the total cover. On the silty clay, sandy loam, and clay loam plots, forbs comprised 78, 50, and 55 percent of the total cover, respectively. The shrub component, which was essentially the same in 1979 as in 1978, has decreased in both density and cover since its peak in 1979. This was the result of mortality of both fourwing saltbush and winterfat during the winters of 1978-1979 and 1979-1980.

Differences in vegetative production on the four types of soil materials were evaluated in 1979 and 1980. In August of both years, all grasses and forbs were clipped from one-fifth of the area of each of the 16 study plots. Half of this sample was taken from the fertilized portion of the study plot, and half from the unfertilized portion. Productivity of shrubs was estimated through the use of the weight estimate method. Clipped vegetation was separated by species and weighed immediately to obtain green weight. After curing for 8 days, air-dry weight was determined. Tables 13 and 13a show mean plant production by plant class in 1979 and 1980 on the fertilized and unfertilized soil material combinations.

Plots of sandy loam topsoil over clay loam produced the greatest weight of plant material in 1979. However, differences in total plant weight among types of soil material were not statistically significant at the five percent confidence level. This was true for both the fertilized and unfertilized portions of the plots. Neither was there a significant difference in forb production on the four soil types. However, the unfertilized portions of the plots of sandy loam over clay loam and loam over clay loam produced significantly greater amounts of grass than the plots of silty clay over clay loam and clay loam alone.

Table 12. Mean percent ground cover by plant class on four soil material combinatio after 1, 2, and 3 years[1]

			Three topsoils (10") over 30" clay loam		
		Clay loam (40")	Sandy loam	Loam	Silty clay
Grasses:	1977	0.7	0.3	<0.1	<0.1
	1978	6.7	8.8	19.3	2.0
	1979	17.2	27.1	34.0	7.6
Forbs:	1977	2.9	9.4	1.6	2.2
	1978	16.0	31.8	13.6	17.0
	1979	32.2	32.8	20.5	40.0
Shrubs:	1977	1.2	1.3	.1	.1
	1978	6.2	6.1	1.0	3.9
	1979	9.5	6.0	1.2	4.0
All classes:					
	1977	4.8	11.0	1.8	2.4
	1978	28.9	46.7	33.0	22.9
	1979	58.9	65.9	55.6	51.6

[1] Does not represent true percent ground cover because of overlap among plants. Values shown in the table are means of four replications.

Table 13. Mean plant production (grams, air-dry) per square meter[1], on fertilized (F) and non-fertilized (NF) plots of four soil material combinations. Utah International cooperative study at Alton, 1979.

	Clay loam (40")		Three topsoils (10") over 30" clay loam					
			Sandy loam		Loam		Silty clay	
Species	F	NF	F	NF	F	NF	F	NF
Crested wheatgrass	179	26	168	112	147	167	64	1
Tall wheatgrass	39	3	44	22	64	70	30	6
Russian wildrye	8	--	6	5	26	4	4	1
Western wheatgrass	2	--	6	2	14	8	2	--
Indian ricegrass	--	--	--	--	--	< 1	< 1	--
All grasses	228	29	224	141	251	250	101	8
Alfalfa	78	237	146	335	89	174	115	309
Small burnet	1	14	1	< 1	9	14	15	25
Cicer milkvetch	1	2	--	< 1	< 1	< 1	< 1	3
Globemallow	--	--	< 1	< 1	< 1	< 1	< 1	< 1
All forbs	80	253	148	338	100	190	132	338
Fourwing saltbush	27	50	15	44	6	3	5	9
Winterfat	< 1	< 1	--	--	1	< 1	1	1
All shrubs	28	51	15	44	7	4	6	10
Totals	336	333	387	523	358	444	239	356
	669		910		802		595	

[1] Plant class totals and grand totals include an allowance of 1 gram per square meter for those species producing less than 1 gram. Tabular values are means of four replications.

Table 13a. Mean plant production (grams, air dry) per square meter, on fertilized (F) and non-fertilized (NF) plots of four soil material combinations. Utah Internation cooperative study at Alton, 1980.

			Three topsoils (10" over 30" clay loam)					
	Clay loam (40")		Sandy Loam		Loam		Silty clay	
Species	F	NF	F	NF	F	NF	F	NF
Crested wheatgrass	105	15	201	197	197	215	72	2
Tall wheatgrass	51	5	27	22	54	24	57	1
Russian wildrye		2	17	1	19	2	3	
Western wheatgrass	4		31	7	23	14		1
Indian ricegrass								
All grasses	160	22	276	227	293	255	132	4
Alfalfa	207	278	276	225	107	134	220	233
Small burnet		< 1	< 1				< 1	3
Cicer milkvetch	< 1	2						
Utah sweetvetch		< 1					< 1	2
All forbs	208	282	277	225	107	134	222	238
Fourwing saltbush	3	2		4		4	3	11
Winterfat	< 1	3						<
All shrubs	4	5	0	4	0	4	3	1
Totals	372	309	553	456	400	393	357	255
	681		1009		793		612	

In 1980, the fourth growing season, the clipped samples indicated that total plant production was significantly greater on the unfertilized sandy loam and loam plots than on the plots of silty clay. Production on the sandy loam plots was also significantly greater than on plots of clay loam. On fertilized plots, total plant production followed the same pattern as on unfertilized plots, but differences between soil materials were not statistically significant.

In contrast to 1979, the 1980 sampling indicated that grass production was significantly greater on both fertilized and unfertilized portions of the plots of sandy loam and loam than on either silty clay or clay loam plots.

By 1980, grasses were producing twice as much plant material as forbs on both fertilized and unfertilized portions of the plots of loam over clay loam. The competition of grass with forbs on these plots has resulted in significantly less forb production on loam plots than on the other three soil materials.

The effect of the single application of inorganic nitrogen and phosphorus fertilizer (at the time of seeding) is interesting. No apparent difference in the stands of vegetation on the four soil materials was evident at the end of the 1977 growing season. However, by the end of the 1978 growing season, grass density was greater on the fertilized part of several plots, and was especially noticeable on the plots of silty clay over clay loam, and clay loam. The one-shot application of fertilizer apparently increased the establishment and vigor of grasses on the silty clay and clay loam soil materials. Through the fourth growing season, forbs did not show a similar response.

Overall plant productivity apparently increased slightly in 1980, compared to 1979. However, the apparent increase may be the result of sampling variation rather than a true increase. "Drylander" alfalfa contributed 94 percent of the forb production in 1979, and 99 percent in 1980. Crested wheatgrass contributed approximately 70 percent of the total grass production in 1979 and 73 percent in 1980. Considering just these two species, plus fourwing saltbush, the productivity on the study plots in 1979 ranged from 1,637 pounds per acre (air-dry weight) on fertilized silty clay plots to 4,371 pounds per acre on unfertilized sandy loam plots. In 1980, the production of "drylander" alfalfa and crested wheatgrass alone ranged from 2,189 pounds per acre on unfertilized silty clay plots to 4,244 pounds per acre on fertilized sandy loam plots.

The study has demonstrated that the type of carbonaceous shale used is suitable for establishing a good stand of vegetation if inorganic fertilizer is added to promote survival and growth of grass species. Leguminose forbs, such as alfalfa, can be successfully established without fertilization. After weathering for several months, the carbonaceous shale has excellent moisture-holding capacity and has been an excellent seed germination medium.

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If either a sandy loam topsoil or a loam topsoil are used to cover carbonaceous shale, excellent stands of vegetation can be established without fertilization. However, fertilization would enhance the establishment of grass species on any combination of soil materials. The silty clay topsoil, derived from Tropic Shale parent material has proven to be the poorest soil material tested with respect to seedling germination and establishment. Silty clay should not be used as a covering material on reclaimed sites.

Throughout the 4 years of study, vegetation on the study plots has exhibited little moisture stress except for brief periods during August and September. Two factors may be responsible for this: (1) over-winter precipitation has been above average every year since the dry winter of 1976-1977, (2) the carbonaceous shale used as a foundation for the soil material combinations is an excellent retainer of soil moisture.

Soil salinity has shown little change over the study period (Table 14). Sodium adsorption ratios have also remained low. In fact, the SAR of carbonaceous shale has shown a decrease each year.

Table 14. Electrical conductivity and sodium adsorption ratio of soil materials on the Alton Study Plots

Soil material	November 1976 ECe[1]	November 1976 SAR[1]	October 1978 ECe[2]	October 1978 SAR[2]	October 1979 ECe[2]	October 1979 SAR[2]
	- - - - - -	- - - - - -	- - m mhos/cm	- - - - - -	- - - - - -	- - - - - -
Carbonaceous shale	3.3	0.5	7.8	1.0	3.0	0.4
Sandy loam topsoil[3]	0.6	.8	2.3	1.0	.5	.7
Loam topsoil[3]	1.1	.6	1.7	1.0	.8	.4
Silty clay topsoil[3]	.6	3.1	1.0	2.0	.5	.7

[1] Composite sample taken at time of plot establishment.

[2] Composite of samples from 4 to 8-inch depth on each of four plots.

[3] Ten inches of topsoil over 30 inches of carbonaceous shale.

Study No. 5 (A Bioassay Greenhouse Study of Different Soils from the Alton Coal Field)

Objectives: (1) To compare different soil profile materials as growing media for plants in the greenhouse, (2) To determine effects of fertilizer amendments on plant growth.

Methods

A factorial study was set up in the greenhouse using four soils, four amendments, and two replications. The same four types of soil overburden used in Study No. 3 from the 3-acre site at the Alton coal field were brought to the greenhouse for testing as growing media for plants as follows:

a. Sandy loam topsoil,

b. Light-colored gravelly-clay subsoil below the topsoil.

c. Blue clay (weathered shale) below "b".

d. Dark-colored carbonaceous shale below "c" (immediately above the coal seam).

Each of the soils was placed 3 inches deep in plastic pans and four amendment treatments were added as follows:

1. Kaibab compost spread 1 inch deep over 3 inches of soil and the two media mixed together.
2. Kaibab compost spread 1/2 inch deep over 3 inches of soil and thoroughly mixed together.
3. Nitrogen in the form of ammonium nitrate applied to soil in pans at a rate of 100 pounds of N per acre.
4. No treatments (control).

Smooth brome and tall wheatgrass were used to test effects of soil and treatments. Fifty seeds of smooth brome were planted in two rows of 25 seeds each in each pan. Tall wheatgrass was planted in the same manner. Dates of seedling emergence were recorded and total emergence determined for each pan. Plants were grown for 60 days in the greenhouse, after which they were measured and harvested for determination of biomass. Height measurements were made at 2-week intervals during the 60-day period. Pans were watered equally.

Results

There was no significant difference in seedling emergence between treatments for either tall wheatgrass or smooth brome. Overall seedling emergence was 98.4 percent for tall wheatgrass and 66.8 percent for smooth brome. Average leaf height was greatest on topsoil for both species and least on blue clay and gravelly subsoil (Tables 15 and 16).

Table 15. Average leaf heights (inches) of tall wheatgrass on four soils*

Topsoil	Dark clay	Gravelly subsoil	Blue clay
8.2	4.9	3.5	3.4

* Means underscored by the same line are not significantly different (P < .05).

In this study there was no significant difference in leaf height attributable to soil amendments. Nitrogen fertilizer did not have the effect that was expected. Whether the watering regime wherein all soils were watered equally would have influenced effects of amendments is unknown. In general, herbage yields tended to follow a similar pattern to leaf heights.

Table 16, Average leaf height (inches) of smooth bromegrass on four soils*

Topsoil	Dark clay	Gravelly subsoil	Blue clay
5.9	2.5	1.5	1.8

* Means underscored by the same line are not significantly different (P < .05).

Study No. 6 (Growth and Development of Selected Container-Grown Shrubs and Forbs on a Drill Pad at Alton)

Objective: (1) To compare rates of growth and development of a fairly large number of shrub species, over time, in order to select those best suited to the area, (2) to select combinations of species that would create habitat diversity for wildlife and birds in addition to forage for livestock.

Methods

A drill pad area on the lower edge of the 8-acre site was smoothed with a dozer blade in the fall of 1976 in preparation for planting containerized shrubs. In mid-June 1977, 25 species of shrubs plus three species of forbs were planted on an area 75 feet wide by 144 feet long. Ten plants of each species were planted in subplots 6 feet by 15 feet in size, on a 3-foot grid spacing. The 28 species plots were replicated four times in a randomized-block design. All plants were container-grown in the greenhouse. Some were 1 year old, and some were only 2-1/2 months old when transplanted in the field.

Results

Data on shrub and forb survival and growth were taken in October 1977, 4 months after planting. Survival of 22 of the 28 species was 90 percent or more. Of the remaining six species, survival was 70 percent or more for all except bush cinquefoil, all plants of which appeared dead. Most vigorous in appearance were fourwing saltbush, wedgeleaf ceanothus, winterfat, rubber rabbitbrush, cliffrose, prostrate summer cypress, and Woods rose.

Survival data were taken again on May 11, 1978, and dead plants were replaced by live plants of the same species, where available, on May 17, 1978. Many plants of bush cinquefoil which appeared dead in October 1977 were found to be alive in May 1978. Six species requiring no replacements included black sagebrush, rubber rabbitbrush, green ephedra, golden currant, Russian olive, and scarlet globemallow. Six species needing only one plant replaced were: big sagebrush, Fremont barberry, Arizona cypress, Utah sweetvetch, cliffrose, and prostrate summer cypress. All other species required four or more replacements. Plants of fourwing saltbush appeared to have very low vigor on May 11, but this particular ecotype might be slow in beginning spring growth.

Fourwing saltbush plants recovered vigor during the 1978 growing season and appeared thrifty in late September 1978. However, nearly all plants appeared dead in the spring of 1979, and they remained that way throughout the 1979 growing season (Table 17). Apparently, this particular ecotype is not well adapted on this site.

In addition to fourwing saltbush, roundleaf buffaloberry showed considerable loss of plants over winter, followed by winterfat and Arizona cypress. These species showed a loss of three or more plants per plot over the 1978-1979 winter, which was generally colder than average.

Table 17. Shrub survival (mean number live plants per plot: 10 possible) over four growing seasons.

		Date				
Common name	Symbol	10/18/77	No. replaced May 1978	9/19/78	9/19/79	9/23/80
Leadplant	Amca	--	40	7.5	7.0	6.0
Serviceberry	Amor	7.8	9	10.0	9.8	8.0
Black sagebrush	Arno	10.0	0	10.0	9.5	9.5
Big sagebrush	Artr	9.2	1	9.5	9.2	8.8
Big vetch	Asgl*	8.2	0	5.8	5.5	2.8
Fourwing saltbush	Atca	9.8	0	9.8	0.5	0.0
Fremont barberry	Befr	10.0	2	10.0	9.8	9.2
Siberian peashrub	Caar	7.2	0	7.5	7.3	7.0
Wedgeleaf ceanothus	Cecu	9.0	4	10.0	10.0	9.8
Winterfat	Cela	9.2	4	9.8	6.0	5.8
Curlleaf mtn. mahogany	Cele	9.2	3	9.2	9.0	9.0
True mtn. mahogany	Cemo	9.2	5	9.8	9.5	9.5
Rubber rabbitbrush	Chna	9.8	0	9.5	9.5	9.5
Cliffrose	Cost	9.2	3	9.8	9.0	9.0
Arizona cypress	Cuar	9.8	1	10.0	7.0	6.0
Russian olive	Elan	10.0	0	9.5	9.2	9.2
Green ephedra	Epvi	10.0	0	9.8	10.0	10.0
Utah sweetvetch	Hebo*	9.8	1	9.2	9.2	9.0
Prostrate summer cypress	Kopr	9.5	1	9.8	9.8	9.8
Tatarian honeysuckle	Lota	9.8	0	9.0	9.0	9.0
Bush cinquefoil	Pofr	10.0	1	3.0	3.0	6.0
Black chokecherry	Prvi	8.0	10	9.8	9.8	9.8
Bitterbrush	Putr	8.5	6	9.5	9.5	9.5
Skunkbush	Rhtr	10.0	4	10.0	9.8	9.8
Golden currant	Riau	9.0	0	10.0	9.5	9.8
Woods rose	Rowo	9.2	4	10.0	10.0	10.0
Blueberry elder	Sace	10.0	0	7.8	7.8	7.8
Roundleaf buffaloberry	Shro	9.5	9	9.0	2.0	1.8
Scarlet globemallow	Spgr*	10.0	0	10.0	9.5	7.8
Squawapple	Pera	--	40	4.5	5.5	5.2
	MEANS	9.3		9.0	8.1	7.8

*Forbs

Species showing most height growth in 1979 included Siberian peashrub, rabbitbrush, Russian olive, black chokecherry, blue elderberry, and Woods rose, all of which showed 7 or more inches height growth (Table 18). In addition, two forbs, Utah sweetvetch and scarlet globemallow, showed excellent growth and were [are] proving well adapted on this site. These plots should be monitored over several more years to determine the relative merits of each species on this site. move center to end of les

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By the end of the fourth growing season since planting, a small amount of mortality had occurred among 14 of the 30 plant species on the site (Table 18). All remaining fourwing saltbush had died during the winter of 1979-1980. Species that appear least adapted to the climate and soils of the test site on the basis of survival include big milkvetch, roundleaf buffaloberry, tatarian honeysuckle, squawapple, winterfat, leadplant, and Arizona cypress. However, several excellent individual plants of buffaloberry, squawapple, and Arizona cypress are present. In fact, the mean annual height growth of Arizona cypress was exceeded by only two species; chokecherry and Russian olive.

Other than the seven species mentioned above, most test species are growing well (Table 18). The wild rose has borne seed for two seasons and is spreading vegetatively. Golden currant and blueberry elder also produced fruit in 1980. Growth of some individual plants can be expected to be less than their potential in future years because of competition among adjacent plants.

After four growing seasons the study has shown that a large variety of shrubs, forbs, and small trees, not all of which are native to the area, are adapted to the climatic conditions of the Alton Coal Field.

Table 18. Increase in mean height and crown diameter of shrubs at Alton Coal Field (4 years)

Species symbol	Height				Crown Diameter			
	10/18/77	9/19/78	9/19/79	9/23/80	10/18/77	9/19/78	9/19/79	9/23/80
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Amca	--	11.9	8.3	8.8	--	3.5	6.3	7.5
Amor	3.8	7.6	11.8	16.0	--	6.0	12.5	16.2
Arno	2.5	6.3	11.3	16.0	--	6.5	12.3	16.8
Artr	7.0	13.0	15.8	18.2	--	12.3	19.8	22.2
Asgl*	4.5	5.3	11.2	9.5	--	10.8	18.3	7.8
Atca	15.5	12.0	7.0	--	--	11.4	4.0	--
Befr	2.8	7.8	9.3	10.8	--	5.0	8.0	9.2
Caar	4.0	8.3	15.8	21.5	--	7.6	14.8	19.5
Cecu	9.8	10.3	14.0	17.8	--	13.0	17.0	21.8
Cela	9.0	9.4	15.5	13.2	--	8.0	13.5	11.5
Cele	4.5	8.0	10.0	15.0	--	6.9	13.0	15.2
Cemo	5.0	7.3	12.8	16.5	--	7.5	13.3	15.5
Chna	11.3	14.0	21.0	22.5	--	17.3	23.0	25.5
Cost	8.3	10.8	16.3	18.5	--	12.6	18.0	21.8
Cuar	6.5	13.5	16.8	26.0	--	9.5	10.8	16.0
Elan	12.8	17.8	25.5	34.2	--	14.8	25.8	30.2
Epvi	8.3	10.8	12.3	14.5	--	7.9	10.8	12.2
Hebo*	5.4	6.3	14.8	17.5	--	10.8	20.8	20.5
Kopr	17.0	21.0	21.8	24.0	--	21.0	24.8	23.2
Lota	14.3	9.5	12.0	16.8	--	5.4	9.8	14.5
Pofr	0.0	3.3	10.0	12.5	--	4.5	10.0	12.0
Prvi	4.8	11.9	21.0	26.5	--	7.4	13.5	17.8
Putr	6.3	7.8	13.3	17.0	--	13.3	17.5	22.0
Rhtr	10.0	10.0	15.8	19.2	--	12.0	21.3	23.2
Riau	6.8	17.3	18.5	23.0	--	15.5	19.3	25.0
Rowo	9.5	12.3	21.3	25.5	--	11.9	22.3	25.2
Sace	6.0	11.5	18.0	21.5	--	16.0	20.5	20.0
Shro	8.3	6.0	9.0	10.5	--	5.0	9.5	10.5
Spgr*	10.0	11.0	17.0	18.2	--	20.5	20.5	18.8
Pera	--	4.3	8.8	12.8	--	1.9	4.3	8.2
MEAN	7.6	10.2	14.5	18.1	--	10.2	15.2	17.6

*Forbs

--No data

Study No. 7 <u>(Compatability of Selected Container-Grown Shrubs with Various Grasses on Four Soil Types)</u>

Objectives: (1) To compare growth rates of 10 selected shrubs in competition with each of 11 selected grasses on different soils.

Methods

In early May 1978, container-grown plants of the following 10 shrub species were planted on one replication described in study No. 3; fourwing saltbush, Bonneville saltbush, winterfat, curlleaf mountainmahogany, true mountainmahogany, green ephedra, prostrate summer cypress (two varieties), skunkbush sumac, and bitterbrush.

A single row of each shrub species was planted across all 11 grass plots on each of the four types of soil. Shrubs were planted approximately 5 feet (1.5 M) apart so that in any single row, two plants occurred in each 10-foot-wide (3 M) grass plot, making a total of 22 plants per row. Rows were also spaced approximately 5 feet (1.5 M) apart so that all 10 shrub species occurred on each of the four types of soil.

Results

All shrub species showed excellent survival at the end of the first growing season and differential survival by the end of the third growing season (Table 19). Greatest decline in numbers of plants between 1978 and 1980 occurred on topsoil plots. Apparently, the heavier grass cover on topsoil plots offers more competition to shrubs than other types of soil materials where grass is less productive. It should be pointed out that one of the main reasons for decrease in plant numbers on dark shale is the fact that the upper terrace sluffed off and many plants close to the edge were destroyed or covered up. Species most affected by sluffing were prostrate summer cypress, curlleaf mountainmahogany, and winterfat. Shrub species showing best overall survival in competition with grasses were fourwing saltbush, villous prostrate summer cypress, and skunkbush.

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From the standpoint of size, superior shrub species are villous prostrate summer cypress, fourwing saltbush, and bitterbrush (Table 19). When Table 19 is compared with Table 7, it is quite apparent that shrubs are better adapted on sterile soil material such as the blue clay and dark shale than are the grasses. Of course, it is known that grasses require nitrogen fertilizer on sterile materials for best productivity. In this study, fertilizer was not added to the different types of soils.

The competitive effect of the various grass species on overall shrub survival and growth is shown in Table 20. In general, grass plots which showed heaviest herbage production such as crested, intermediate, and tall wheatgrass plots showed lowest shrub survival at the end of the 1980 growing season. On the other hand, native grasses such as bluebunch, streambank, and western wheatgrasses and Great Basin wildrye allowed highest shrub survival, along with Russian wildrye.

Table 19. Mean number of plants, height, and crown diameter of 10 shrub species according to soil type at Alton (Sep) 1978, 1979, 1980.*

		Topsoil			Blue clay			Dark shale			Gravelly subsoil			Means		
Shrub species symbol	Year	No. plants	Ht. In.	Crown dia. In.	No. plants	Ht. In.	Crown dia. In.	No. plants	Ht. In.	Crown dia. In.	No. plants	Ht. In.	Crown dia. In.	No. plants	Ht. In.	Crown dia. In.
CEMO	1978	21	9.4	2.3	22	10.0	3.0	20	7.1	3.0	22	6.9	2.7	21.2	8.4	2.8
	1979	16	9.9	4.0	21	8.8	5.2	17	8.5	5.8	19	7.7	5.1	18.2	8.7	5.0
	1980	11	6.6	2.9	21	9.2	7.2	17	10.5	7.9	17	8.1	6.4	16.5	8.6	6.1
PUTR	1978	12	8.2	3.9	19	6.7	4.0	21	7.1	4.1	21	7.0	6.6	18.2	7.3	4.6
	1979	13	9.1	7.4	16	11.8	12.1	15	12.1	13.5	21	13.8	15.0	16.2	11.7	12.0
	1980	11	12.2	12.4	17	13.3	18.1	17	15.9	18.5	21	19.8	20.9	16.5	15.3	17.5
RHTR	1978	21	9.5	3.1	22	9.1	3.4	22	6.9	3.1	22	7.9	3.3	21.8	8.4	3.2
	1979	20	6.8	4.5	20	10.9	7.4	22	8.3	7.1	22	8.5	6.6	21.0	8.6	6.4
	1980	17	7.9	5.1	20	11.6	11.0	22	9.1	8.4	19	8.5	6.3	19.5	9.3	6.4
EPVI	1978	22	7.1	3.8	22	6.9	4.1	22	6.7	3.4	22	6.9	3.7	22.0	6.9	3.8
	1979	15	8.3	4.4	21	11.1	6.4	18	5.5	3.4	20	7.8	4.5	18.5	8.2	4.7
	1980	9	10.5	4.4	21	10.7	7.3	18	4.5	3.0	20	6.5	3.3	17.0	8.1	4.5
CELE	1978	20	6.6	2.7	20	4.8	2.1	21	4.5	2.4	22	4.5	2.5	21.8	5.1	2.4
	1979	16	9.1	5.0	19	7.6	4.4	1	10.0	9.0	22	6.9	4.9	14.5	8.4	5.8
	1980	16	9.7	6.4	20	8.5	5.7	1	17.0	14.0	22	7.0	5.1	14.8	6.0	7.8
CELA	1978	22	9.8	5.6	22	8.5	4.2	22	9.6	6.6	20	5.7	4.2	21.5	8.4	5.2
	1979	18	10.6	6.0	15	11.2	7.6	11	7.3	5.6	18	10.6	6.0	15.5	9.9	6.3
	1980	15	10.1	7.0	15	9.4	8.5	11	5.2	4.0	9	5.5	4.0	12.5	7.5	5.9
ATBO	1978	20	5.2	3.8	22	4.6	4.0	22	11.4	10.8	22	8.4	7.9	21.5	7.4	6.6
	1979	12	5.4	4.1	20	7.7	7.1	13	8.4	8.0	12	5.4	4.1	14.2	6.7	5.8
	1980	6	5.0	2.2	15	6.2	6.6	6	4.2	3.8	11	8.4	6.8	9.5	6.0	4.9
KOPR	1978	18	4.1	4.4	22	3.7	4.6	20	7.1	9.8	21	13.8	19.3	20.2	7.2	9.5
	1979	12	16.6	7.9	19	18.6	13.4	5	22.5	14.0	12	16.6	7.9	12.0	18.6	10.8
	1980	11	13.0	7.6	18	15.3	13.8	5	18.2	19.2	20	29.4	29.4	13.0	19.0	17.5
ATCA	1978	22	7.0	5.8	22	6.5	6.6	22	15.8	16.9	22	17.8	18.0	22.0	11.8	11.8
	1979	21	10.5	6.0	22	12.0	11.5	22	13.1	15.2	19	28.2	26.7	21.0	16.0	14.8
	1980	17	9.8	5.2	20	12.5	12.5	19	13.6	13.7	21	24.3	22.5	19.2	15.1	13.5
KOVI	1978	22	10.0	7.0	22	5.5	4.9	22	7.2	7.2	22	12.3	12.0	22.0	8.8	7.8
	1979	20	21.0	12.5	22	25.3	19.2	22	26.0	17.4	20	21.0	12.5	21.0	23.3	15.4
	1980	19	16.6	10.3	21	19.7	14.0	17	25.7	19.8	19	19.0	14.0	19.0	20.3	14.5
MEANS	1978	20.0	7.7	4.2	21.5	6.6	4.1	21.4	8.6	6.7	21.6	9.1	8.0	21.1	8.0	5.8
	1979	16.3	10.7	6.2	19.5	12.5	9.4	13.3	11.1	9.0	18.5	12.6	9.3	16.9	11.7	8.5
	1980	13.2	10.1	6.4	18.8	11.6	10.5	13.3	12.4	11.2	17.9	13.6	11.9	15.8	11.9	10.0

* Twenty-two plants of each species were planted on each soil type.

Table 20.--Overall shrub survival and mean height and mean diameter according to grass species plots.

Grass species	Shrubs			
	No.	Percent survival	$\bar{x}$ Ht.(in)	$\bar{x}$ Dia.(in)
Agcr	54	68	13.6	11.2
Agel	55	69	11.3	9.2
Agin	63	79	12.6	10.2
Agin[2]	50	62	10.1	8.5
Agri	60	75	12.1	9.7
Agsm	65	81	12.2	10.5
Agsp x Agre	51	64	12.9	11.4
Agtr[2]	55	69	10.4	8.9
Brin	56	70	12.0	10.3
Elci	64	80	13.6	12.4
Elju	63	79	12.8	10.5

Study No. 8 (Exploratory Study on Adaptability of Tree-Like Species)

Objectives: (1) To determine whether certain tree species will survive and grow on severely disturbed soils in this environment.

Methods

This should be regarded as a preliminary study to determine whether additional work is justified with some of the species being tested. Species used in this study were some available in containers from Couer d'Alene Nursery and other sources as follows: bur oak, bigtoothed maple, horse chestnut, black chokecherry, American plum, and poplar. Most plants were less than 1 foot in height.

Plants were transferred to the field from containers in the spring of 1978. The six species were planted on contour trenches that had been made in 1977 with a dozer blade on the 3-acre Alton site where the slope is 25 percent or greater. A Lating Square design was used so that one plant of each species appeared in each row and each column. Rows corresponded to single contour trenches. Plants were spaced approximately 8 feet apart in both directions, in adjacent Latin Squares.

Results

At the end of the first growing season, bigtooth maple showed best survival of any species (92 percent) (table 21). However, it showed greatest winter mortality of any species, and only two of 12 plants were alive at the end of the third growing season and these were very small. Poplar showed slightly higher survival than any of the six species at the end of the third growing season. It appears that all of these plants will succumb to keen competition from grass, but that should not preclude additional testing in the absence of grass competition.

Table 21. Percent survival of six tree species at end of each of the first three growing seasons.

Year	Oak	Bigtooth maple	Horse chestnut	Black chokecherry	Poplar	American plum
1978	33	92	42	50	67	42
1979	25	8	8	33	50	42
1980	0	17	0	0	25	17

?

Study No. 9 (Microclimatological Studies)

Objectives: (1) Instrumentation has been established over several years on the three experimental sites described in this report; including the 8-acre study site, 3-acre study site, and Utah International Cooperative study site. Objectives were to monitor soil moisture, air and soil temperatures, and soil salinity of reconstructed sites over a period of time. Effort on each of the sites is discussed separately.

Utah International Study Site

Methods:

Soil moisture sensors and soil salinity sensors were installed in December 1976 at three depths, at a single location, within each of the 16 plots (4 soils x 4 replications). Depths were 20, 46, and 76 cm (8, 18, and 30 in. respectively) below the soil surface. Locations were at the same point within each plot; 2.1 m (7 ft.) below the upper edge and 1.5 m (5 ft.) in from the sides.

Soil moisture and salinity were monitored on five occasions during the 1977 growing season. Soil moisture was monitored at weekly intervals from early May through October 30 in both 1978 and 1979 and from late May through September in 1980. Soil salinity was measured in early May from sensors and at the end o October from soil samples in both 1978 and 1979, and from soil samples in November 1980.

Results:

The winters of 1977-1978, 1978-1979, and 1979-1980, were unusually wet throughout most of southern Utah wherein the study sites are located. This was fortunate because the growing seasons of 1978 and 1979 were considerably drier than usual. The growing season of 1980 was slightly wetter than usual, because of twice the long-term average rainfall being received in September.

The first soil moisture measurements in 1980, on May 24, indicated that soil moisture was slightly greater at the 8-inch depth than at the same date in 1979. However, at the 18- and 30-inch depths (in clay loam material) soil moisture content was similar to that recorded in 1979. This probably indicates that in years when the overwinter precipitation is quite plentiful soil moisture storage will be essentially the same, at depths below 12 inches, at the onset of the growing season.

The soil moisture regime on the study plots during the 1980 growing season was remarkably similar to that observed in 1979. All soils were near field capacity at the beginning of the last week in May 1980. At this time the soil moisture was essentially the same at the 18-inch and 30-inch depths on all plots (all sensors at these depths were in clay loam). As in 1979, soil moistur gradually decreased in all soil materials until about mid-June. Thereafter only a small amount of additional moisture was lost (table 22).

Table 22. Mean soil moisture percent in shale overburden and three topsoil-shale overburden combinations on the Utah International study plots (1980).

	May 24	May 31	Jun 7	Jun 14	Jun 21	Jul 19	Aug 15	Sep 14	Sep 28
Clay loam overburden									
8"	18	16	12	12	11	11	11	11	10
18"	20	20	17	14	14	13	13	12	12
30"	21	20	20	17	15	14	14	14	14
Sandy loam									
8"	12	9	8	8	8	7	7	12	8
18"	20	20	16	14	13	13	13	13	13
30"	20	20	19	14	13	13	12	12	12
Loam									
8"	25	22	21	21	21	21	21	20	20
18"	19	18	12	10	10	9	9	9	8
30"	20	20	19	14	13	12	12	12	12
Silty clay									
8"	28	26	23	21	21	21	20	22	21
18"	20	20	19	14	13	13	12	12	12
30"	20	19	20	19	13	11	10	10	10

Eight-acre Study Site

Methods:

On May 17, 1979, a battery-powered (solar-charged) automatic data logger was installed at the 8-acre study area on the Alton Coal Field. This instrument monitors four sensors at hourly intervals and stores the data on magnetic tape. Measurements are taken of air temperature at 12 and 54 inches above the ground, soil temperature at a depth of 8 inches, and precipitation.

In addition, on June 1, 1979, single-junction thermocouple psychrometers were embedded in the soil of each of the six soil type-soil amendment combinations on one replication of the study plots. Three locations were selected on each soil type-soil amendment area. An effort was made to select locations where an area of at least 2 square feet of bare soil occurred. This was done to minimize the effects of plant roots on soil water content. At each selected location, psychrometers were placed at depths of 8 and 20 inches. The first measurements of soil water potential were made on June 21. Beginning on July 7, measurements were made at essentially weekly intervals through October 30, 1979. In 1980, the first measurements were made on May 1. However, problems with the microvoltmeter used to obtain readings from the thermocouple psychrometers prevented further data from being obtained until July 12. Thereafter, readings were taken at weekly intervals through September 28, 1980.

Results:

Table 23 shows the monthly mean, mean maximum, and mean minimum air and soil temperatures for the period of mid-May, 1979, through April, 1980. Data for the growing season of 1980 has not yet been summarized. Table 24 shows monthly extreme temperatures recorded at the eight-acre study area. The frost-free season at the eight-acre site was 118 days long in 1979 compared to a frost-free period of 124 days at Alton and 173 days at Kanab. However, our data were taken at a height of 12 inches above the soil surface, whereas data from Alton and Kanab were taken at a height of 54 inches.

Table 25 shows mean soil water potential, expressed in bars, at approximately 14-day intervals through the 1980 observation period, as obtained from readings of the thermocouple psychrometers.

Table 23. Mean mean maximum, and mean minimum air and soil temperatures (C°), May 18, 1979 through April 30, 1980. Alton 8-acre study area.

	Air @ 54"	Air @ 12"	Soil @ -8"
Mean maximum			
May (18-31)	22.8	24.4	15.6
June	26.8	29.4	20.4
July	31.6	35.4	24.3
August	28.6	31.5	23.2
September	28.5	32.3	21.8
October	21.4	28.5	17.1
November	8.8	11.4	6.6
December	9.1	11.4	3.2
January	6.6	4.5	1.9
February	10.8	3.7	1.7
March	8.8	5.4	1.7
April	15.2	17.3	8.5
Mean			
May (18-31)	14.1	13.6	14.5
June	18.4	17.6	19.0
July	22.2	21.4	22.9
August	19.4	19.0	21.8
September	18.9	18.1	20.6
October	12.5	11.5	16.1
November	1.2	.4	6.0
December	.5	- .8	2.7
January	.0	- .8	1.9
February	2.5	- .1	1.7
March	1.5	.0	1.4
April	7.9	7.7	7.6
Mean minimum			
May (18-31)	6.5	4.7	13.5
June	9.0	6.1	17.6
July	12.4	8.9	21.5
August	11.0	7.9	20.6
September	10.2	6.2	22.5
October	4.5	.2	15.1
November	- 4.8	- 8.8	5.5
December	- 5.6	- 9.6	2.2
January	- 4.3	- 4.7	1.6
February	- 3.6	- 2.7	1.7
March	- 4.7	- 5.1	1.2
April	1.0	- 1.0	6.8

Table 24.--Monthly extreme temperatures (C°) recorded at the 8-acre study area, Alton Coal Field.

	Air				Soil	
	54 inches		12 inches		8 inches	
	Max.	Min.	Max.	Min.	Max.	Min.
May 1979	27.2	1.5	28.9	0.1	16.3	12.5
June	34.0	0.2	36.7	0.0	23.7	14.1
July	35.3	7.5	39.7	4.5	26.1	19.6
August	36.0	5.4	40.2	3.7	26.6	16.1
September	33.1	4.8	37.5	0.7	23.6	17.1
October	29.1	- 7.8	33.2	-12.3	20.2	8.9
November	13.7	-12.0	16.6	-16.3	9.8	1.5
December	17.4	-14.5	20.0	-20.6	5.2	0.7
January 1980	15.7	-10.7	10.2	-11.3	2.5	0.6
February	18.6	-12.8	9.8	-10.6	2.1	1.1
March	18.6	-11.0	12.2	-14.7	4.3	0.8
April	25.3	- 5.9	27.3	- 7.0	11.4	2.0

Table 25.--Mean soil water potential (-bars)[1] at the two depths. Soil type - soil amendment combinations. Alton 1980.

	5/1	7/12	7/21	8/6	8/22	9/5	9/20	9/28
Topsoil/hay								
8"	11.0	3.6	4.7	6.1	8.2	9.6	7.4	5.0
20"	10.0	1.0	3.1	3.1	4.9	5.6	5.3	6.0
Topsoil/check								
8"	8.3	4.0	5.2	7.4	10.1	12.8	10.3	8.6
20"	13.0	2.6	4.8	6.1	7.8	8.8	8.3	7.9
Topsoil/compost								
8"	9.6	6.0	8.6	9.2	6.3	8.5	5.6	6.0
20"	16.0	1.7	2.8	2.8	2.7	3.8	3.0	3.1
Subsoil/hay								
8"	8.8	2.6	4.0	5.5	4.9	6.3	3.2	4.9
20"	13.1	2.4	2.8	2.4	2.1	2.6	2.2	2.5
Subsoil/check								
8"	13.5	5.0	6.7	7.9	5.0	7.2	2.4	5.3
20"	15.2	1.0	2.5	1.4	---	1.6	1.0	2.5
Subsoil/compost								
8"	17.4	2.2	5.4	4.6	2.5	4.3	1.6	4.3
20"	15.1	2.5	3.6	---	2.4	2.3	2.8	1.8

[1]Each value in the table represents the mean of measurements taken at three locations.

Data from soil water potential measurements indicate that on May 1, subsoils tended to have lower soil water potentials than topsoils, although the difference was not large. By July 12, this relationship was beginning to reverse itself. From July 21 through the remainder of the summer the subsoils tended to have higher soil water potentials than the topsoils. These data may indicate that the subsoils have lower water holding capacity, but retained somewhat more water on these study plots. The reasons why this may be the case are uncertain. However, the suboil may have a greater clay content than the topsoil, it may remain cooler because of being lighter-colored, and the lower density of vegetation on subsoil plots could result in less soil moisture being removed through transpiration from soil surrounding the psychrometer.

It should be noted that soil water potential is a measure of the tension by which soil holds water and not a measure of the water content of soil.

Three-acre Study Site

Methods:

On June 1, 1979, single-junction thermocouple psychrometers were embedded in the soil of each of the four soil types involved in this study. Three locations were selected on each soil type. As on the 8-acre area, an effort was made to select locations where an area of at least 2 square feet of bare soil occurred. This was difficult to do on the topsoil plots because of the overall high density of grass. At each selected location, psychrometers were placed at depths of 8 and 20 inches. The first measurements of soil water potential were made on June 21. Beginning on July 7, measurements were made at essentially weekly intervals until October 30, 1979. As on the 8-acre study area, first measurements of soil water potential in 1980 were made on May 1. Subsequent measurements were made at weekly intervals from July 12 through September 28, 1980.

Table 26 shows mean soil water potential, expressed in bars, at approximately 14-day intervals throughout the summer of 1980. In 1980, the water potential of the four different soil types on the three-acre study area followed nearly the same pattern as exhibited in 1979. The considerable difference in texture among the four soils makes interpretation of water potential measurements difficult. At the 8-inch depth, the ripped topsoil displayed lower soil water potentials throughout the season than did the other three soil materials. This may be due primarily to a greater loss of water through transpiration, as grass density was much greater on the topsoil plots than on the other soils. At a depth of 20 inches soil water potentials were quite high in all soils throughout the period of observation. Even at soil water potentials of -8 or -9 bars, as occurred at a depth of 8 inches in topsoil, plants should be under very little moisture stress.

Table 26.--Mean soil water potential (-bars)[1] at two depths on four soil types. Alton three-acre site, 1980.

	5/1	7/12	7/21	8/6	8/22	9/5	9/20	9/28
Ripped topsoil								
8"	2.6	3.9	5.3	6.6	8.8	9.0	3.5	5.1
20"	13.7	0.8	0.6	1.1	3.6	4.6	3.0	3.5
Ripped subsoil								
8"	8.9	2.9	1.9	3.2	2.8	3.5	2.1	1.1
20"	9.0	1.2	1.2	1.5	0.8	0.5	1.4	1.3
Shale terrace								
8"	9.7	1.3	2.8	4.0	3.1	4.9	3.9	4.0
20"	10.9	0.9	3.0	1.5	1.1	1.4	2.1	2.0
Transported subsoil								
8"	16.4	2.1	3.7	4.9	5.7	6.0	6.4	5.9
20"	11.8	1.4	3.6	1.2	0.5	1.0	2.5	0.9

[1]Each value in the table represents the mean of measurements taken at three locations.

Study No. 10 (A Comparison of Selected Ecotypes of Atriplex Canescens at the Alton Coal Field.)

Objectives: (1) To determine superior ecotypes of *Atriplex canescens* at the Alton coal field from the standpoint of survival and herbage production.

Methods:

One ecotype of *Atriplex canescens* obtained from Las Lumas, New Mexico, winterkilled in the second growing season in Study No. 6 at Alton. Therefore, we consider it highly important to test different sources of this species to determine which ones are superior in this area. Three replications of 20 ecotypes of *Atriplex canescens* were planted in a randomized-block design May 1, 1980. These were planted in the upper corner of a 4-acre site located a short distance from the 8-acre site at Alton. This site was reconstructed by Utah International, Inc. in the fall of 1979 following opening of a pit to obtain samples of the underground coal. Five container-grown plants of each ecotype were planted per row 20-feet-long and spaced 4 feet apart within the row, with 4 feet between rows as shown on the accompanying diagram.

Data on plant survival and growth were obtained September 24, 1980. All plants were alive with the exception of two plants in a slight depression that had been covered by deposition of soil during a summer rainstorm. Maximum height growth among accessions ranged from 8 to 22 inches during the first growing season. Maximum crown diameter among the 20 accessions ranged from 7 to 21 inches. Survival and growth will be monitored at the beginning and end of each growing season for at least the next 2 years.

	Block 3	Block 2	Block 1
	← 56' →		
1	Sanpete	71706	79669
2	79663	79428	79678
3	Myton	79659	79428
4	Yuma 79678	79667	79706
5	Johnson	79713	79663
6	7972	79656	79686
7	79686	79802	79710
8	U-3675	79726	79776
9	79802	79686	Myton
10	79706	Johnson	U-3675
11	79659	79663	79656
12	79726	Sanpete	79659
13	79669	79685	79713
14	79656	7972	79667
15	79428	79776	79685
16	79776	79678	7972
17	79685	71710	79802
18	79713	79669	79726
19	79710	Myton	Johnson
20	79667	U-3675	Sanpete

Accessions List

79713	Tulerosa,
79656	Joshua forest,
79667	Guaymas, Mexico
79678	Yuma, AR
7972	Yuma (35 mi E), AR
79659	Vermallo, NM
79428	Huntington, UT.
79776	Jericho sand dunes, UT.
79685	Adrian, OR.
79686	Nyssa, OR.
79663	Delta, Colorado
79706	Holbrook,
79669	Douglas, Wyoming
71710	Tuba-Flagstaff turnoff (gigas)
79802	Jericho sand dunes (lin), UT
79726	Tucson, AR.

Johnson Canyon, UT.
Myton, UT.
U36-75 → U-3675 ?
Sanpete 70058-0, UT.
} USFS Shrub Lab

→ U-3675 Excel Canyon (Ephraim)
U36-75

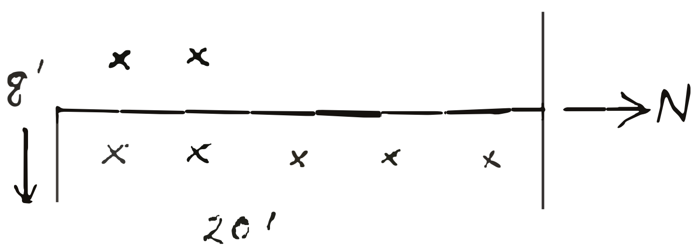

Diagram of Atriplex canescens plant at Alton site, May 1, 1980.

Study No. 11 (Establishment and Growth of Container-grown Plants on Reconstructed Soil Above a Coal Bulk Sampling Site)

Objectives: (1) To evaluate the survival and growth of 27 species of plants (four trees, 15 shrubs, six forbs, and two grasses) established by transplanting container-grown planting stock. (2) To evaluate the aesthetic value of a combination tree and shrub planting, wherein plants are provided optimum spacing and are arranged in a windbreak pattern.

Methods

In the autumn of 1979, Utah International, Inc. excavated soil and overburden material to a depth of approximately 40 feet in order to acquire coal samples from a mineable coal seam. After obtaining the samples, the open pit was refilled and the terrain was restored to its approximate original contour. The sampling site was located on a south-facing, 5 percent slope. An area of approximately 3.5 acres of reconstructed soil material resulted from the restoration.

Location of the study area is on public domain land administered by the Bureau of Land Management, U.S. Department of Interior, in the SW 1/4 of Section 18, Township 40 South, Range 4-1/2 West, Kane County, Utah. It is on coal lease lands held by Utah International, Inc.

Elevation at the site is approximately 6,550 feet (1 977 m). Average annual precipitation is about 14 inches. Native vegetation of the surrounding area is dominated by a *Juniperus osteosperma* - *Pinus edulis* community. Primary understory plants are shrubs and trees, including true mountain mahogany (*Cercocarpus montanus*), bitterbrush (*Purshia tridentata*), Fremont barberry (*Berberis fremontii*), and Gambel oak (*Quercus gambelii*). Openings within the pygmy forest community are dominated by big sagebrush (*Artemisia tridentata*), black sagebrush (*Artemisia nova*), and green rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. *graveolens*).

The portion of the bulk sampling site that was selected for planting is virtually free of any native weedy vegetation since the soils on the area were so greatly mixed during opening of the pit and subsequent refilling and leveling.

In the spring of 1980, container-grown planting stock of the plant species to be evaluated was planted by hand in holes made with a gas-powered soil auger. No supplemental water was given to the plants, either at the time of planting, or during the 1980 growing season.

The planting was done in two separate parts. On one area, 22 accessions (one accession each of 18 species and two accessions each of two species) were planted in a randomized block design, with four blocks. Five plants of each accession were planted in each block. Plant species in this planting included relatively small-sized shrubs, forbs, and grasses. Spacing was on a 4-foot grid.

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On a second area, seven species of larger-sized shrubs and trees were planted in the form of a windbreak. Two rows of 10 plants of each species were planted. The tallest-growing species occupy the center of two rows, and the outer six rows in each direction are occupied by species of successively smaller form. Rows of the windbreak are oriented in approximately a north-south direction. Spacing is 8 feet between rows and 10 feet between plants within a row.

The entire 3.5-acre area was fenced by Utah International to exclude rabbits. However, small rodents and mule deer will be able to enter the fenced area.

Data will be recorded on plant survival and growth during September of each year for as long as the plantings are considered to provide useful information. If opportunity permits, data will also be taken on overwinter survival during May of each year.

The plantings were made on May 28, 1980. The following table lists the plant species used, the source of each species, and the age of the planting stock at the time of planting.

Table 27. List of plant species planted on the Alton bulk sampling site, May 1980.

Species planted in randomized block design:			
Spco	*	Sphaeralcea coccinea	(Alton 3-acre site)
Spco	*	Sphaeralcea coccinea	(Utah International site)
Rhtr	*	Rhus trilobata	(South of Enterprise, Utah)
Acla	*	Achillea lanulosa	(Southern Idaho)
Celem	*	Ceanothus lemmoni	(B1-71, Shasta Co., California)
Cebe	*	Cercocarpus betuloides	(B1-72, Red Bluff, California)
Cela	*	Ceratoides lanata	(East of Kanab, Utah)
Cepa	*	Ceratoides papposa	(Green Canyon, Lot #1)
Chna	*	Chrysothamnus nauseosus	(Sprague Gulch, Colorado)
Come	*	Cowania mexicana	(Northplan Company, Utah source)
Erco	*	Eriogonum corymbosum	(Glendale, Utah)
Peve	*	Penstemon venustus	(Northplan)
Pugl	*	Purshia glandulosa	(Warm Springs, Nevada)
Yucca	*	Yucca sp.	(Washington County, Utah)
Hija	**	Hilaria jamesii	(New Mexico, Lot #3)
Stco	**	Stipa comata	(Sandy, Utah)
Arfi	$	Artemisia filifolia	(U8-74, Bullfron, Hite Junction, Uta
Juho	***	Juniperus horizontalis	(B3-76, Rosebud County, Montana)
Fapa	***	Fallugia paradoxa	(Spring Shores, Idaho)
Hebo	*	Hedysarum boreale	(Salt Lake County, Utah)
Rowo	***	Rosa woodsii	(B18-71, Rosebud County, Montana)
Rowo	***	Rosa woodsii	(Alton, Utah)
Species planted in windbreak design:			
Amut	$	Amelanchier utahensis	(U7-67, Enterprise, Utah)
Cemo	***	Cercocarpus montanus	(Colorado Springs, Colorado)
Cuar	*	Cupressus arizonica	(Kern Co., California)
Frve	*	Fraxinus velutina	(South of Enterprise, Utah)
Popz	***	Populus (hybrids)	(Cuttings from Coeur d'Alene nursery
Prvi	***	Prunus virginiana	(U27-77, Hobble Creek, Utah Co., Uta
Quga	*	Quercus gambelii	(Cannonville Road, Kane Co., Utah)

* = 1980 planting stock, 3 months old when planted; ** - 1979 planting stock, 15 months old when planted; *** = 1978 planting stock, 27 months old when planted; $ = 1977

Table 28 shows the mean percent survival and mean height and diameter of plants after the first growing season on the randomized block study plot.

Table 28. Mean percent survival, and mean size of plant species on reconstructed soil at Alton after one growing season.

Table missi

Species symbol	Mean % survival	Mean height (inches)	Mean diameter (inches)
Acla	100	4.5	8.0
Arfi	90	12.0	7.0
Celem	100	10.0	6.0
Cebe	90	4.0	3.0
Cela	80	3.6	4.0
Cepa	90	9.5	7.0
Chna	95	12.2	8.5
Come	100	9.5	6.8
Erco	100	8.8	9.8
Fapa	95	11.8	5.0
Hebo	100	5.8	6.2
Hija	100	7.2	4.5
Juho	80	3.8	2.8
Peve	100	4.2	3.8
Pugl	100	7.8	5.8
Rhtr	100	12.5	4.0
Rowo (Alton)	100	9.2	9.5
Rowo (Montana)	95	10.8	6.8
Spco (Alton)	100	13.5	13.8
Spco (Ut. Int.)	95	18.5	14.5
Stco	85	9.0	5.5
Yucca	100	5.2	4.0

Table 29 shows the mean percent survival and mean height and diameter of plants after the first growing season on the windbreak study plot.

Table 29. Mean percent survival, and mean size of plant species on reconstructed soil at Alton after one growing season (windbreak planting pattern).

Species symbol	Mean % survival	Mean height (inches)	Mean diameter (inches)
Amut	85	8.5	4.0
Cemo	90	7.5	4.0
Cuar	100	6.0	3.5
Frve	90	3.0	2.5
Quga	95	2.5	2.5
Popz	100	17.5	12.0
Prvi	95	6.0	3.5

In November, 1980 soil samples were taken from the study site for physical and chemical analyses. Results have not been received from the Utah State Soils Laboratory, and will be included in the next progress report.

Study No. 12. Role of Mycorrhizal Fungi in Mineral Uptake and Nutrition of plants Used in Revegetation of Mine Spoils

Objective: To assess the association of mycorrhizal fungi with host plants.

Methods

The association of a mycorrhizal fungus with a host plant root is known to increase plant growth and aid in uptake of nutrients, especially phosphorus. Recent studies by several investigators indicate that most of the climax plant species in western rangelands are vesicular-arbuscular (VA) mycorrhizal. Establishment of VA mycorrhizal relationships will likely prove important in rehabilitation of reconstructed soils on western mined lands.

A preliminary survery of plants growing on reconstructed soils and also on undisturbed sites at our research locations revealed a high frequency of mycorrhizal colonization. A spore population study is currently underway in order to determine the species of VA fungi present at each site and the relative numbers of each. Soil samples were collected from the root region of the major species growing on three different soil types. Spore identification has so far revealed *Glomus fasciculatus* as a common member of the spore population.

The following native species at Alton were mycorrhizal: *Artemisia nova*, *Astragalus* species, *Cymopterus purpureus*, *Chrysothamnus nauseosus*, *Leucocrinum montanum*, *Sphaeralcea coccinea*, *S. parvifolia*, and *Zygadenus paniculatus*. *Castilleja chromosa* was not mycorrhizal.

Roots of crested wheatgrass collected from different soil treatments were mycorrhizal for the following treatments: Subsoil plus hay, topsoil check, undisturbed topsoil, and topsoil plus hay. Roots from subsoil were not mycorrhizal.

The study will continue for at least another year.

Outlook

Studies described in this report were conducted on various experimental sites as follows:

Studies No. 1, 2, and 6 on the 8-acre site,
Studies No. 3, 7, and 8 on the 3-acre site,
Study No. 4 on the Utah International site,
Study No. 5 in the greenhouse in Provo,
Study No. 9 on the 8-acre and Utah International sites,
Studies No. 10 and 11 on the Utah International 4-acre (new in 1980)
Study No. 12 - general.

These studies should be monitored for the next 2 years at least, to determine changes with time and increase in the data base. Results to date enabled us to assist the BLM in the summer of 1980, in answering allegations by petitioners against surface mining in the Alton coal field. Also, we made a presentation as part of the BLM response at the hearing in Kanab on September 29, 1980.

At least one field tour (and others as needed) will be conducted for Agency personnel and other interested parties in the summer of 1981, to view progress.

APPENDIX

LIST OF PLANT SPECIES CITED IN THIS REPORT

GRASSES

Symbol	Scientific Name	Common Name
Agcr	Agropyron cristatum	Fairway wheatgrass
Agel	A. elongatum	Tall wheatgrass
Agin	A. inerme	Beardless bluebunch wheatgrass
Agin(2)	A. intermedium	Intermediate wheatgrass
Agri	A. riparium	Streambank wheatgrass
Agsm	A. smithii	Western wheatgrass
Agtr(2)	A. trichophorum	Pubescent wheatgrass
Agsp X Agre	A. spicatum X A. repens	Hybrid wheatgrass
Brin	Bromus inermis	Smooth brome
Elci	Elymus cinereus	Great Basin wildrye
Elju	E. junceus	Russian wildrye
Orhy	Oryzopsis hymenoides	Indian ricegrass
Spai	Sporobolus airoides	Alkali sacaton

FORBS

Symbol	Scientific Name	Common Name
Asci[2]	Astragalus cicer	Cicer milkvetch
Asgl	A. globiceps	Big milkvetch
Basa	Balsamorhiza sagittata	Arrowleaf balsamroot
Hebo	Hedysarum boreale	Utah sweetvetch
Meme	Medicago media	"Drylander" alfalfa
Mesa	M. sativa	Alfalfa
Meof	Melilotus officinalis	Yellow sweetclover
Pepa	Penstemon palmeri	Penstemon
Sami	Sanguisorba minor	Small burnet
Spco	Sphaeralcea coccinea	Scarlet globemallow
Sufr	Sutherlandia fruticosa	Sutherlandia
Swsa	Swainsona salsula	Swainsonpea

TREES AND SHRUBS

Amca	Amorpha canescens	Leadplant
Amor	Amelanchier oreophilus	Serviceberry
Arno	Artemisia nova	Black sagebrush
Artr	A. tridentata	Big sagebrush
Atbo	Atriplex bonnevillensis	Bonneville saltbush
Atca	A. canescens	Fourwing saltbush
Befr	Berberis fremontii	Fremont barberry
Caar	Caragana arborescens	Siberian peashrub
Cecu	Ceanothus cuneatus	Wedgeleaf ceanothus
Cela	Ceratoides lanata	Winterfat (whitesage)
Cepa	C. papposa	Plumed whitesage

TREES AND SHRUBS continued

Symbol	Scientific Name	Common Name
Cele	Cercocarpus ledifolius	Curlleaf mountainmahogany
Cemo	C. montanus	True mountainmahogany
Chna	Chrysothamnus nauseosus	Rubber rabbitbrush
Cost	Cowania mexicana	Cliffrose
Cuar	Cupressus arizonica	Arizona cypress
Elan	Eleagnus angustifolia	Russian-olive
Epne	Ephedra nevadensis	Nevada ephedra
Epvi	E. viridis	Green ephedra
Eubu	Euonymus bungeanus	Euonymus
Fone	Forestiera neomexicana	New Mexico forestiera
Grsp	Grayia spinosa	Spiny hopsage
Kopr	Kochia prostrata	Prostrate summer cypress
Koprv	K. prostrata var. villosissima	Villous summer cypress
Lota	Lonicera tatarica	Tatarian honeysuckle
Pera	Peraphyllum ramosissimum	Squawapple
Posp	Populus spp.	Cottonwood
Pofr	Potentilla fruticosa	Bush cinquefoil
Prme	Prunus melanocarpa	Black chokecherry
Putr	Purshia tridentata	Bitterbrush
Rhtr	Thus trilobata	Skunkbush sumac
Riau	Ribes aureum	Golden currant
Rowo	Rosa woodsii	Woods rose
Sace	Sambucus cerulea	Blueberry elder
Shro	Shepherdia rotundifolia	Roundleaf buffaloberry